Summer of Innovation

Rocketry: Learning Newton's Laws through Rocketry
4th – 9th grade
Version 2

Introduction

The goal of the NASA Summer of Innovation Rocketry camp is to excite young minds and inspire trainee trainees toward future science, technology, engineering, and mathematics (STEM) pursuits. Raising trainee achievement in STEM pursuits begins by leading trainees on a journey of understanding through these highly engaging activities. The activities and experiences in this guide come from across NASA's vast collection of educational materials.

This themed camp outline provides examples of one-day, two-day, and weeklong science and engineering programs. Each day contains 6-8 hours of activities totaling more than 35 hours of instructional time. The camp template will assist you in developing an appropriate learning progression focusing on the concepts necessary to engage in learning about rockets. The activities scaffold to include cooperative learning, problem solving, critical thinking, and hands-on experiences. As each activity progresses, the conceptual challenges increase, offering trainees full immersion in the topics.

Intended Learning Experiences

Through the participation in these camps future scientists and engineers will have the opportunity to explore Rocketry. Student trainees gain learning experiences that help make scientific careers something they can envision in their lives. Trainees realize that they have the potential to make a contribution to this field and ignite their curiosity to see what they might create during the program. The learning experiences also anticipate that trainees will have the opportunity to:

- Gain a foundation for learning the math and science principles essential for rocketry
- Explain and predict Newton's Laws of Motion and how it applies to rockets
- Investigate the pioneers, and advancements that have made the U.S. the leader of modern space exploration
- Identify characteristics of successful parachute, payload, fin, nose cone and body styles of various rockets
- Apply the Engineering Design Process for various projects
- Recognize the significance of propulsion and different kinds of fuel
- Predict outcomes of the Engineering Design Process and make modifications in various hands-on projects
- Demonstrate the concepts of trajectory, stability, center of mass, center of pressure, and altitude measurement
- Raise awareness of the skills needed for a career with NASA and other STEM fields

Professional Development

Educator Professional Development (PD) experiences are available. Webinars, NASA Digital Learning Network (DLN) programs, training videos, and online meeting spaces will help you implement the program. We hope that you and your trainees have a memorable and successful experience implementing these activities.

Professional Development Resources

- The NASA Educator Online Network is a great resource for STEM educators to share and learn about STEM topics. The Rocketry camp hosts a group that will provide a place for sharing about the activities, additional resources, extension ideas, and support.
- Visit the Summer of Innovation homepage for an extensive catalog of news, media resources, and educational materials.

Format of the Guide

$ Requires simple materials common in the classroom or relatively inexpensive to obtain.

$$ Requires purchasing unique materials such as poster board, duct tape, or hot glue guns.

$$$ Requires purchasing or building higher-cost items, though many are one-time purchases that may used for many trainees over several years

The Six E's

Each day or section of activities utilizes the 5-E Instructional Model. Included in this program guide is a sixth 'E' for Excite. This additional 'E' shows you how to incorporate NASA's unique information and resources to excite trainees with career connections, real world examples, spinoffs from NASA research, and more. Learn more about the 5-E Instructional Model.

Title	Overview	Time	Cost	Additional Resources
The title hyperlinks to the activity.	An overview describes the main concepts and strategies used in the lesson, activity, or demonstration.	The time listed includes time for an introduction, activity time, and conclusion time.	Please find this camp or the activity you are using in the Resource Repository for more information on costs and tips.	Suggested resources may include additional lesson plans, posters, images, or other learning support materials.

Engage: Question?

Icons may appear throughout the program

A computer symbol means you may need one or more computers or other technology, though alternatives are available.

The pencil icon helps to identify the journal.

Journal

Journals are an optional element of your camp. Throughout the camp template, you will find reflective questions, ideas, and guidance in creating a journal. Journals also provide trainees with a unique souvenir of their experiences. Learn more about how scientists and engineers use journaling at NASA by watching this eClip video: Journaling in Space.

One - Day Program: Rocketry Camp

This one-day camp is designed to introduce the basic rocketry concepts of Newton's Laws of Motion and the Engineering Design Process. Trainees will also build and launch simple rockets. The learning progression moves from learning Newton's Laws to applying the information to create their own balloon powered rockets, rocket cars, and payload rockets.

Title	Overview	Time	Cost	Additional Resources
Simple Rocket Science	Trainees will make predictions and race balloons horizontally along string across the room. Trainees will be introduced to Newton's Third Law of Motion.	30 min as a demo	$	
Explore: Newton's Third Law				
Rocket Races	Trainees will draw out designs for balloon powered rocket cars. Then using Styrofoam meat trays will build and race vehicles. Trainees will be introduced to the Engineering Design Process.	1.5 hrs	$	Click here to learn about teaching the "Engineering Design Process",
Explain: Newton's Third Law				
Heavy Lifting	Trainees will design a balloon rocket system for carrying the most paperclips (payload) to the ceiling.	1.5 hrs	$	
Elaborate: Newton's Third Law				
Paper Rockets	Trainees will build a simple paper rocket. Please use the stomp rocket launcher in this activity.	1.5 hrs	$$	
Altitude Tracker	Trainee will build an altitude tracker to measure the height of various rocket launches during the week.	0.5 hrs	$	
Evaluate: Newton's Third Law				
Rocket Launch	Trainees will launch rockets. Trainees will record results and compare them with the class for design and height. Have teams analyze key factors that might have influenced the height achieved by different rockets. This could include the shape of fins, nose cones, etc.	0.5 hrs	$	

Debrief	Review key concepts of the day: • Newton’s Laws of Motion • Gravity • Engineering Design Process • Altitude Tracking • Parts of a Rocket	15-30 min		Debrief questions located in Resource Repository *Rocket Journal*
Excite: NASA Connection				
Video	At any point during the day, trainees can watch video of astronauts on the International Space Station (ISS) talking about Newton’s Laws of Motion. Trainees can also see a short video clip on the new Space Launch System (SLS) which is NASA’s new rocket system that will go to the ISS beginning in approx. 2017. • *Newton's Laws On-Board the International Space Station* from eClips	0.5 hrs		
Total		**7 hrs**		

Two-Day Program – Day One: Rocketry Camp

This two-day program is designed to introduce the basic rocketry concepts of Newton's Laws of Motion and the Engineering Design Process. Trainees will design, build and launch simple rockets. After the first launch, trainees will make design modifications to improve performance and include more complex features. Trainees will also learn more in depth information about design elements impacting altitude tracking and trajectory.

Title	Overview	Time	Cost	Additional Resources
Simple Rocket Science	Trainees will make predictions and race balloons horizontally along string across the room. Trainees will be introduced to Newton's Third Law of Motion.	0.5 hrs	$	
Explore: Newton's Third Law				
Rocket Races	Trainees will draw out designs for balloon powered rocket cars. Using Styrofoam meat trays they will build and race vehicles. Introduce trainees to the Engineering Design Process.	1.5 hrs	$	To learn more see the Engineering Design Process video here.
Explain: Newton' Third Law				
Heavy Lifting	Trainees will design a balloon rocket system for carrying the most paperclips (payload) to the ceiling.	1.5 hrs	$	
Elaborate: Newton's Third Law				
Paper Rockets	Trainees will build a simple paper rocket and launch it. After the launch they will evaluate possible improvements to designs. In Day Two, trainees will improve designs and make modifications to factors such as payloads, parachutes, nose cones, and fin designs. Please use the stomp rocket launcher in this activity.	1.5 hrs	$	
Altitude Tracker	Trainees will build an altitude tracker to measure the height of various rocket launchers during the week.	0.5 hrs	$	

Evaluate: Newton's Third Law				
Rocket Launch	Trainees will launch paper rockets. Trainees will record results and compare these results to design factors and height achieved. After rocket launches, trainees will determine what design elements could be modified to increase the altitude.	0.5 hrs	$	
Debrief	Review key concepts of the day: • Newton's Laws of Motion • Gravity • Engineering Design Process • Trajectory • Altitude Tracking • Parts of a rocket	15-30 min		Debrief questions located in Resource Repository *Rocket Journal.*
Excite: NASA Connection				
Video	At any point during the day, trainees will watch video of Astronauts on the International Space Station talking about Newton's Laws of Motion. Trainees will see short video clip on the new Space Launch System (SLS). • *Newton's Laws On-Board the International Space Station* from eClips • http://www.nasa.gov/exploration/systems/sls/sls1.html	20 min		
Total		**7 hrs**		

Two-Day Program – Day Two: Rocketry Camp

The second day of the two-day Rocketry Camp is designed to expand on the basics of Newton's Laws of Motion, engineering design process, and expand learning to include the role of fuel in rocketry. Trainees will enhance the designs of their rockets utilizing the engineering design process. Trainees will learn historical milestones in rocket development.

Title	Overview	Time	Cost	Additional Resources
Simple Rocket Science #2	Trainees will determine how much the air in a balloon affects the distance the rocket will travel. Trainees will discover what happens when the string is moved to a vertical position. This is not part of the original lesson plan, but a great extension activity to reinforce the concepts of fuel amounts, the impact of gravity/ drag, and the application of Newton's 2nd Law of Motion.	1.0 hrs	$	
Explore: What impact does fuel have?				
Film Canister Rockets -	Trainees will construct a rocket powered by an effervescing tablet reacting with water. Make the connection of combining liquid and solid fuels in film canister rockets to modern rockets. Activity found on page 58.	1.0 hrs	$	
Explain: History of Rocketry				
History of Rocketry	Trainees will learn about key people who designed rockets and draw pictures of different rockets. What types of technology were typical of this person's time? What other project was this person working on? What future inventions were they possibly thinking about but didn't get to?	1.0 hrs	$	Images/Facts from Rocket Educator Guide
Elaborate: Newton's Law and design elements				
Paper Rock	Trainees will improve designs and make other modifications to payloads, parachutes, nose cones and fin types.	1.5 hrs	$	Lesson Plan Part 2
Evaluate: Rocketry Concepts				

Foam Rockets	Trainees will construct rockets made from pipe foam and use them to investigate trajectory relationships between launch angle and range.	1.0 hrs	$$	
Rocket Launch	Trainees will launch the paper rockets. Trainees will record results and compare them to design factors.	0.5 hrs	$	
Debrief	Review key concepts of the day: • Newton’s Laws of Motion • Gravity • Engineering Design Process • Trajectory • Altitude Tracking • Solid/ Liquid Fuels • Historical Milestones • Parts of a Rocket	15-30 min		Debrief questions located in Resource Repository *Rocket Journal*.
Excite: NASA Connection				
Video	Before building rockets, trainees will watch a series of three videos. Launchpad Videos: *Cryogenics in Transportation, Liftoff with Solid Rocket Boosters*, and *Firing the Space Shuttle Main Engines* from eClips	20 min		
Total		**6.5 hrs**		

Weeklong Program – Day One: Rocketry Camp
Newton Did It, Can You?

The focus of Day One is introducing trainees to the principle of Newton's Laws of Motion. Several activities will allow the trainees to see the laws in action. Trainees will work in small groups to predict outcomes based on those laws of motion and use activities to determine if predictions were correct. Day One will also introduce the Rocket Journal the trainees will keep all week to document learning. It can be used as an assessment tool and souvenir of the week. Trainees will be introduced to the weeklong Water Bottle Rocket (X-51) project.

Title	Overview	Time	Cost	Additional Resources
Rocket Journal 	Trainees will design a cover for their Rocket Journal for the weeklong camp. The use of the journal will document concepts and ideas covered during the week. The journal will be used in group discussions after individual reflection. Journals can serve as assessment at the end of the week. Time should be given at the beginning and end of activities to journal key ideas.	15 min and during week	$	Template - Resource Repository *Rocket Journal.*
Simple Rocket Science	Trainees will make predictions and race balloons horizontally along string across the room. Trainees will be introduced to Newton's Third Law of Motion.	30 min as a demo	$	
Explore: Newton's Third Law				
Move It - Found on Page 32	Trainees will test action reaction results with balloons after making predictions in small groups. Trainees will document predictions and results in their Rocket Journals.	0.5 hrs	$	
Rocket Races	Trainees will draw designs for balloon powered rocket cars. Using Styrofoam meat trays they will build and race vehicles. Trainees will document predictions, designs, and their understanding of Newton's Third Law in their journals. Trainees will also be introduced to the Engineering Design Process.	2.0 hrs	$	To learn see the "Engineering Design Process" video here.

Simple Rocket Science #2	Trainees will determine how much the air in a balloon affects the distance a rocket will travel. Trainees will discover what happens when the string is moved to a vertical position. This is not part of the original lesson plan, but a great extension activity that reinforces the concepts of fuel amounts, the impact of gravity/ drag, and Newton's 2nd Law of Motion. In journals, trainees will document observations and chart data.	1.0 hrs	$	
X 51 - Water Bottle Rocket	Trainees will begin the X-51 project, form companies, and design logos. Trainees will also learn all guidelines for the weeklong project.	1.0 hrs	$	Activities in *Rocket Journal*
Debrief	Review key concepts of the day: • Newton's Laws of Motion • Gravity • Engineering Design Process	15- 30 min		Debrief questions located in *Rocket Journal*
Explore: NASA Connection				
Video	At any point during the day, trainees will watch this video of Astronauts on the International Space Station talking about Newton's Laws of Motion. Launchpad: *Newton's Laws On-Board the International Space Station* from eClips.	20 min		
Total		**7 hrs**		

Weeklong Program – Day Two: Rocketry Camp
Lift This Way!

Trainees will learn about the concept of aerodynamics and how each element relates to performance of rockets. Trainees will also learn about key rocket pioneers.

Title	Overview	Time	Cost	Additional Resources
Engage: History				
History of Rocketry	Trainee will learn about key people in rocket development and draw pictures of the rockets. What types of technology were typical of this person's time? What other project was this person working on?	30 min – 1 hour	$	Images/Facts from Rocket Educator Guide
Engage: How much can you carry?				
Heavy Lifting	Trainees will design a system for carrying the most paperclips to the ceiling.	2.0 hrs	$	Data Sheet in *Rocket Journal*
Explore: Learning about factors that influence distance.				
Launch It	Trainees will make simple straw rockets and compare distances of different launches. This activity is from the Design Squad.	1.0 hrs	$	Data Sheet in *Rocket Journal*
Elaborate: Building Rockets				
Paper Rockets	Trainees will build a simple paper rocket and launch them. After the launch they will evaluate possible improvements to designs. In Day Four, trainees will improve designs and make modifications to payloads, parachutes, nose cones and fin designs. Please use the stomp rocket launcher in this activity.	1.5 hrs	$	
Altitude Tracker	Trainees will build an altitude tracker to measure the height of rocket launches during the week.	0.5 hrs	$	
Evaluate: Rocket Performance				
Rocket Launch	Trainees will launch paper rockets. Trainees will record results and compare them to design and height. After the rocket launches, trainees will determine what design elements could be modified to increase the altitude.	0.5 hrs	$$$	Data Sheet in *Rocket Journal.*

Debrief	Review key concepts of the day: • Unbalanced Force • Rocket Pioneers • Aerodynamics • Lift • Potential and Kinetic Energy • Parts of a Rocket	15-30 min		*Debrief Questions in Rocket Journal*
Total		**7 hrs**		

Weeklong Program – Day Three: Rocketry Camp
The Need for Speed!

Day Three will focus on the various types of fuel and how specific design elements impact performance. Trainees will use their previous rocket launches as learning tools in the design process. Then they will go through a series of learning opportunities to learn how to improve individual elements of rocket design and begin to predict the outcome of their modifications.

Title	Overview	Time	Cost	Additional Resources
Engage: What kind of fuel?				
Fuel	After watching the eClips videos about solid and liquid fuels, answer questions in the *Rocket Journal* about the role fuels play in rocket propulsion. Show Launchpad Videos: Cryogenics in Transportation, Liftoff with Solid Rocket Boosters, and Firing the Space Shuttle Main Engines from eClips.	1.0 hrs		Discussion questions in *Rocket Journal*
Explore: How much fuel?				
Film Canister Rockets Page 58	Trainees will construct a rocket powered by an effervescing tablet reacting with water. Make the connection between the combination of liquid and solid fuels in film canister rockets and modern rockets. Use the Altitude Tracker to collect data. (Do not test for temperature in this round).	1.0 hrs	$	Data Sheet in *Rocket Journal*
Explain: What about the temperature?				
Film Canister Rockets Page 58	Trainees will explain the reactions by testing the effect of water temperature and comparing data to previous results.	1.0 hrs	$	Data Sheet and Discussion Questions in *Rocket Journal*
Elaborate: Investigating multistage rockets				
Balloon Staging	Trainee will design a rocket simulating a multistage rocket launch by using two inflated balloons sliding along a fishing line.	1.0 hrs	$	Data Sheet in *Rocket Journal*
Explain: Understanding Trajectory				
Foam Rockets	Trainees will construct rockets made from pipe foam and use them to investigate trajectory relationships between launch angle and range in a controlled investigation.	1.5 hrs	$$	Data Sheet in *Rocket Journal*

Evaluate: Beginning the X 51 Project				
X 51 Water Bottle Rocket	Design budgets, proposals, and early designs. Using the information learned so far in the week, trainees will begin designing water bottle rockets for the culminating activity.	1.5 hrs		Project Packet in *Rocket Journal*
Debrief	Review key concepts of the day: • Fuel • Solid/ Liquid • Trajectory • Motion • Staging • Temperature • Careers	15-30 min		*Rocket Journal*
Excite: NASA Career Connection				
Astronauts/ Careers	What do you have in common with Astronauts? Using NASA websites trainees will learn about astronauts from the trainees' state/region and determine commonalities. Information found at the following websites. Link to African American Astronaut NASA Fact Sheet Link to Hispanic American Astronaut Fact Sheet Astronaut Bios Women @ NASA website	0.5 hrs		
Total		**8 hrs**		

Weeklong Program – Day Four: Rocketry Camp
Design to the Stars!

Trainees will conduct experiments on different nose cone designs and parachute designs. Trainees will make modification to paper rockets from earlier in the week, adding payloads, parachutes and altering nose cone designs. Utilizing information learned, they will finalize water bottle rockets designs in preparation for water bottle launches on Day Five.

Title	Overview	Time	Cost	Additional Resources
Engage: How can the nose cone shape impact aerodynamics?				
Nose Cone Experts - Found on page 90	Trainees will experiment with different nose cone shapes to determine the advantages and disadvantages of each type. In this activity, trainees test conic-, parabolic- and flat-shaped nose cones to determine which is most aerodynamic.	1.0 hrs	$$	Activities in *Rocket Journal*
Explore: How do parachutes work?				
Parachute Designs - Lessons found on page 77, 81, 100, and 103	Trainees will design and test parachutes to examine the relationship between drop time, acceleration, velocity and conclude by building an egg drop lander.	2.0 hrs	$	Activities in *Rocket Journal*
Explain: What is the legacy of rocket designs?				
American Rocket Designs	Review the American Rocket Program from Explorer 1 to the Space Launch System (SLS). Have trainee note characteristics of each rocket and the progression of their design.	1.0 hrs	$	Video on History of Rockets
Elaborate: Improving rocket design.				
Paper Rockets	Trainees will improve designs and make other modifications to payloads, parachutes, nose cones and fin types.	1.5 hrs	$	Lesson Plan Part 2
Evaluate: Water Bottle Rocket Project				
X 51 - Water Bottle Rocket	Utilizing knowledge gained in other events today, trainees will start “purchasing” materials and building their designs. Trainee will make a scale drawing and test rockets for Center of Mass, and Center of Pressure.	2.0 hrs		Activities in *Rocket Journal*

Debrief	Review key concepts of the day • Conic & parabolic shapes • Aerodynamic • Drop time, acceleration, velocity • Center of mass • Center of pressure	15 min		*Rocket Journal* 
Excite: What is next for NASA?				
New NASA Rocket Design SLS	Trainees will learn more details about the new Space Launch System (SLS) Concept. Video of Space Launch System (SLS) at http://www.nasa.gov/exploration/systems/sls/sls1.html	15 min		
Total		**8 hrs**		

Weeklong Program – Day Five: Rocketry Camp
Go For Launch!

Trainees complete a test launch of water bottle rockets and then make final modifications for a final launch at Parent/ Community Open House events. The Open House also highlights the various projects and lessons learned over the week displayed at trainee stations.

Title	Overview	Time	Cost	Additional Resources
Engage: Water propelled engines				
Pop Hero Can	Trainees will construct water-propelled engines from soft drink cans. They test the engines and variables affecting the action-reaction of the engines.	1.0 hrs	$	Data Sheet in *Rocket Journal*
Explore: Launch of water bottle rockets				
X 51 - Water Bottle Rocket	Rocket Launch Day- Test and redesign the rockets.	2.0 hrs	$$	Data Sheet in *Rocket Journal*
Debrief	Review rocket launch.	15 min		Debrief questions In *Rocket Journal*
Excite: Video of Mars Rover Curiosity's Rocket Launch				
Video	Trainees will watch the latest rocket launch to Mars and learn about the next generation of rockets. Rocket and Rover Ready for Flight	15 min	$	
Explain: Creating trainee stations for Open House				
Prepare for Open House	Working in small groups trainees will decide which demonstrations from earlier in the week they would like to display at the Open House. Trainees will create posters highlighting lesson learned.	2.0 hrs	$	
Evaluate: Open House and Demonstrations				
Open House	Trainees will have stations set up around the room and will demonstrate to parents and community leaders what they learned and did over the week. A final rocket launch event will be held demonstrating each rocket built. Awards could be presented if desired.	1-3 hrs		
Total		**8 hrs**		